US Army Research Laboratory

NATO-IST-124 Experimentation Instructions

by Kelvin M Marcus

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14. ABSTRACT

The North Atlantic Treaty Organization (NATO) Science and Technology Organization IST-124 task group, "Heterogeneous Tactical Networks: Improving Connectivity and Network Efficiency", is currently undertaking an effort to develop and distribute an emulation environment and vetted, militarily realistic Extendable Mobile Ad-Hoc Network Emulator (EMANE) scenario that provides a rich combination of elements for experimentation in heterogeneous networks. The EMANE scenario includes detailed mobility and radio models for a battalion-sized operation over the course of 2 h, which has been developed by military experts in planning and performing real exercises. The experimentation environment being developed provides the NATO-IST-124 panel with capabilities to meet their objectives, which is to provide architecture and design guidance for tactical heterogeneous networks for more reliable and predictable network performance through adaptive and efficient control schemes. This report provides guidance and instructions for executing the NATO-IST-124 panel's emulation environment. Specifically, it contains the instructions for executing the EMANE emulation of a single company (24 nodes) from the NATO-IST-124 experimentation scenario in the Dynamically Allocated Virtual Clustering management system hosted in the US Army Research Laboratory's Network Science Research Laboratory.

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1. Introduction

The North Atlantic Treaty Organization (NATO) Science and Technology Organization IST-124 task group, "Heterogeneous Tactical Networks: Improving Connectivity and Network Efficiency", is currently undertaking an effort to develop and distribute an emulation environment and vetted, militarily realistic Extendable Mobile Ad-Hoc Network Emulator (EMANE) scenario that provides a rich combination of elements for experimentation in heterogeneous networks. The EMANE scenario includes detailed mobility and radio models for a battalion-sized operation over the course of 2 h, which has been developed by military experts in planning and performing real exercises. The experimentation environment being developed provides the NATO-IST-124 panel with capabilities to meet their objectives, which is to provide architecture and design guidance for tactical heterogeneous networks for more reliable and predictable network performance through adaptive and efficient control schemes. This report provides guidance and instructions for executing the NATO-IST-124 panel's emulation environment. Specifically, it contains the instructions for executing the EMANE emulation of a single company (24 nodes) from the NATO-IST-124 experimentation scenario in the Dynamically Allocated Virtual Clustering (DAVC) management system hosted in the US Army Research Laboratory's (ARL) Network Science Research Laboratory (NSRL).

2. Experiment

The experimentation environment in the NSRL includes ARL's virtual experimentation cluster deployment software; the DAVC management system; customized virtual machine templates built to run the scenario defined by the NATO-IST-124 panel; and flexible scripting and EMANE configuration files that give users the ability to launch all or subsets of the entire 273-node scenario for experimentation. The scenario in its entirety comprises several vignettes including a 157-node vehicular convoy, whose mobility and path loss were obtained from actual military field operations, troop (3 platoons) and unmanned aerial vehicle movements into an area of operations, naval support, insurgency engagement and neutralization, improvised explosive device neutralization, and medical evacuation of wounded.

3. Instructions

The following instructions detail the DAVC cluster configuration, including deploying the experimentation scenario and emulating the first company (24 nodes shown in Fig. 1) from the scenario. These instructions can be applied to emulate any combination of the nodes involved in the scenario.

id	group	wideband1	wideband2	wideband3	wideband4	narrowband1	narrowband2	narrowband3	satcom	uav	iridium	cellular	tacsat-hf	ugs-net	navy-uhf	navy-hf
network	subnets	192.168.1.0	192.168.2.0	192.168.3.0	192.168.4.0	192.168.5.0	192.168.6.0	192.168.7.0	192.168.8.0	192.168.9.0	192.168.10.0	192.168.11.0	192.168.12.0	192.168.13.0	192.168.14.0	192.168.15.0
1	company1	1	0	0	0	50	0	0	0	0	0	0	0	0	0	0
2	company1	100	0	0	0	150	0	0	0	0	0	0	0	0	0	0
3	company1	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	company1	250	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	company1	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	company1	350	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	company1	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	company1	450	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	company1	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	company1	550	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	company1	600	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	company1	650	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	company1	700	0	0	0	0	0	0	750	0	0	0	0	0	0	0
14	company1	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	company1	850	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	company1	900	0	0	0	0	0	0	950	0	0	0	0	0	0	0
17	company1	1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	company1	1050	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	company1	1100	0	0	0	0	0	0	0	1150	0	0	0	0	0	0
20	company1	1200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	company1	1250	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	company1	1300	0	0	0	0	0	0	0	1350	0	0	0	0	0	0
23	company1	1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	company1	1450	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 1   Company1 network plan

This documentation assumes the following:

- Users have access to the DAVC version 2.0 web application running in the NSRL.

- The NATO-IST-124 virtual machine (EMANE_9.2.1_13G) is registered with DAVC version 2.0.

- Users have access to the NATO-IST-124 experimentation package (nato-experimentation.tar.gz) containing the EMANE scenario, configuration files, radio models, and experimentation scripting.

3.1 DAVC Cluster Configuration

The following are the steps for configuring the DAVC cluster:

1) Access the DAVC version 2.0 web application and create a cluster of 25 nodes using the "EMANE_9.2_13G" virtual machine with the following 2 networks: 172.15.0.0/24 and 172.16.0.0/24 (Figs. 2 and 3).

Fig. 2   Assign the cluster name and description

Fig. 3   Add networks to the cluster

2) Add the 2 networks to all 25 nodes and create the cluster (Fig. 4).

Fig. 4   Add cluster nodes and assign networks
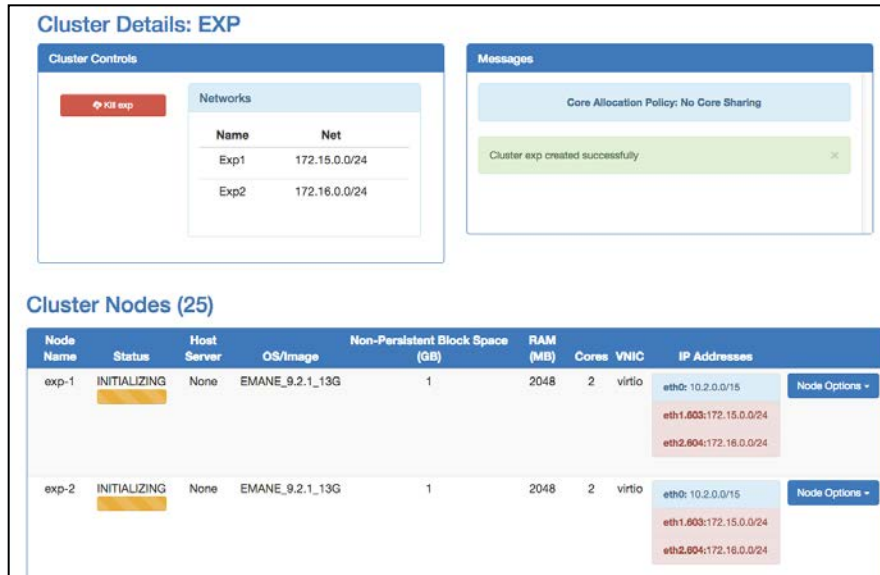
3) Launch the cluster (Fig. 5).

Fig. 5   Launch the cluster

4) Once the cluster is active, log into node 25's virtual network computing (VNC) console (Fig. 6):

   a) The 25th node will bootstrap the other 24 nodes with the necessary EMANE configuration files and scripts and start the experiment with the first company.

   b) It will also run the EMANE event service, which sends location and path loss data to the EMANE event daemons that will run on the other 24 nodes.

Fig. 6   Log into node 25's VNC console

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3.2 Deploy Experimentation Package on the Bootstrap Node

The following are the steps for deploying the experimentation package on the bootstrap node:

1) From node 25, remote copy (*scp*) the "nato-experimentation.tar.gz" file from the local machine to the /opt directory on node 25 (Fig. 7).

Fig. 7   Copy the experimentation package to node 25

2) Extract the contents into the /opt directory on node 25 (Fig. 8).

Fig. 8   Extract the experimentation package

3) All of the EMANE configuration and radio model files are separated by group in the /opt/nato-experiment/scenarioConfig_with_NEMs_v5 directory (Fig. 9).

Fig. 9   Experimentation package EMANE configuration files for company1

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3.3 Deploy Experimentation Package on the Cluster Nodes

The following are the steps for deploying the experimentation package on the cluster nodes:

1) From the bootstrap node (node 25), remote copy the "nato-experiment.tar.gz" file to the other 24 nodes (Fig. 10).

```
Connected (unencrypted) to: QEMU (exp-25)
root@exp-25:/opt# for i in `seq 1 1 24`; do scp /opt/nato-experiment.tar.gz exp-$i:/opt/.; done
nato-experiment.tar.gz                                      100%    48MB   48.3MB/s    00:00
nato-experiment.tar.gz                                      100%    48MB   48.3MB/s    00:01
nato-experiment.tar.gz                                      100%    48MB   48.3MB/s    00:00
nato-experiment.tar.gz                                      100%    48MB   48.3MB/s    00:01
nato-experiment.tar.gz                                      100%    48MB   48.3MB/s    00:01
nato-experiment.tar.gz                                      100%    48MB   48.3MB/s    00:01
nato-experiment.tar.gz                                      100%    48MB   48.3MB/s    00:01
nato-experiment.tar.gz                                      100%    48MB   48.3MB/s    00:01
nato-experiment.tar.gz                                      100%    48MB   48.3MB/s    00:01
nato-experiment.tar.gz                                        0%     0     0.0KB/s    --:-- ETA
```

Fig. 10   Remote copy the experimentation package to the other 24 nodes

2) From the bootstrap node (node 25), remotely extract the contents into the /opt directory on the other 24 nodes (Fig. 11). This will take a few minutes to complete.

```
Connected (unencrypted) to: QEMU (exp-25)
root@exp-25:/opt# for i in `seq 1 1 24`; do ssh exp-$i -C "tar -xzvf /opt/nato-experiment.tar.gz --d
ir /opt/." ; done
```

Fig. 11   Remote extraction of the experimentation package on other 24 nodes

3.4 Configure Experimentation Parameters

The following are the steps for configuring the experimentation parameters:

1) On the bootstrap node (node 25), change the directory to /opt/nato-experiment (Fig. 12) to show the experimentation package contents.

```
Connected (unencrypted) to: QEMU (exp-25)
root@exp-25:/opt# cd nato-experiment/
root@exp-25:/opt/nato-experiment# ll
total 56
drwxr-xr-x  4 root root  4096 Aug 23 14:05 ./
drwxr-xr-x 12 root root  4096 Sep 20 09:33 ../
-rwxr-xr-x  1 root root   216 Aug 23 11:24 commandNodes.sh*
drwxr-xr-x  2 root root  4096 Aug 23 11:24 eventserviceConfigs/
-rwxr-xr-x  1 root root  7951 Aug 23 11:24 launch_exp_local.sh*
drwxr-xr-x 34 root root  4096 Aug 23 11:24 scenarioConfig_with_NEMs_v5/
-rw-r--r--  1 root root 13411 Aug 23 11:24 scenarioConfig_with_NEMs_v5.csv
-rwxr-xr-x  1 root root   911 Aug 23 11:24 start_emane_eventservice_local.sh*
-rwxr-xr-x  1 root root  1521 Aug 23 14:05 start_emane.sh*
-rwxr-xr-x  1 root root   310 Aug 23 14:05 stop_emane.sh*
```

Fig. 12   Experimentation package contents

2) Edit the "launch_exp_local.sh" script file (Fig. 13) and update the following variables:

   a. Update CLUSTER_NAME to the name of the cluster. The cluster name is "exp" in this example.

   b. Update CLUSTER_SIZE to the number of nodes that will be used for the experiment. Since company1 has 24 nodes, we use this value and not 25, because node 25 will only run the experiment and will not be an active node in the experiment.

   c. Update the ACTIVE_GROUPS array by setting to "true" the groups that will be involved in the experiment. Since we are only running company1, we set it to true. All the other groups are set to "false".

Fig. 13   Edit the "launch_exp_local.sh" script file

3) Edit the "stop_exp.sh" script file (Fig. 14):

   a. Update CLUSTER_NAME to the name of the cluster.

   b. Update CLUSTER_SIZE to the number of nodes that will be used for the experiment. Since company1 has 24 nodes, we use this value and not 25, because node 25 will only run the experiment and will not be involved in the experiment.

Fig. 14   Edit the "stop_exp.sh" script file

4) Edit the "start_emane_eventservice_local.sh" script file. This file contains commands to start several instances of the EMANE event service for location and path loss events of the various groups in the experiment:

   a. Comment out the lines as shown in Fig. 15:

      i. Company1 needs the location events specified in "eventservice_locations.xml".

     ii. Referring to the network plan at the top of this report, we see that company1 also needs the wideband1 path loss events specified in "eventservice_wideband1.xml".

   iii. Note there are no event service files for the path loss for narrowband1 and satcom for company1. As of the writing of this report, the .eel files for these radio models have not been generated.

Fig. 15   Edit the "start_emane_eventservice_local.sh" script file

   b. Set the "sleep" command in the last line to the length of time in seconds; the event service, and thus the scenario, should run.

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3.5 Launch the Experiment

The following are the steps for launching the experiment:

1) From the bootstrap node (node 25), execute the "launch_exp_local.sh" script file (Fig. 16).

Fig. 16   Execute the launch script

This script file does the following:

a. Reads the ACTIVE_GROUP array to determine which groups should be started in the experiment.

b. Chooses one of the 24 DAVC cluster nodes and assigns it to a group node from the scenario. For example, the first group node from company1, "company1-1", will be started on the first DAVC cluster node "exp-1" and so on up to "company1-24" on the DAVC cluster node "exp-24".

c. Reads the network plan file to determine which radio models to start on the chosen node.

d. Launches the "start_emane.sh" script with the corresponding EMANE radio model configuration files on the chosen node. This will create the corresponding EMANE interfaces on the chosen node. EMANE interfaces for node "company1-1" hosted on DAVC cluster node "exp-1" are shown in Fig. 17. Interface emane0 corresponds to the wideband1 radio. EMANE interface emane4 corresponds to the narrowband1 radio, but it will not be functional because path loss events will not be generated for that radio model, as mentioned in Section 3.4.

Fig. 17   Node company1-1's EMANE interfaces

e. Creates an updated host file with hostnames for each node in the experiment corresponding to the radios they possess and copies it to each node. An example host file is shown in Fig. 18.


```
192.168.1.1 company1-1-wideband1
192.168.5.1 company1-1-narrowband1
192.168.1.2 company1-2-wideband1
192.168.5.2 company1-2-narrowband1
192.168.1.3 company1-3-wideband1
192.168.1.4 company1-4-wideband1
192.168.1.5 company1-5-wideband1
192.168.1.6 company1-6-wideband1
192.168.1.7 company1-7-wideband1
192.168.1.8 company1-8-wideband1
192.168.1.9 company1-9-wideband1
192.168.1.10 company1-10-wideband1
192.168.1.11 company1-11-wideband1
192.168.1.12 company1-12-wideband1
192.168.1.13 company1-13-wideband1
192.168.8.1 company1-13-satcom
192.168.1.14 company1-14-wideband1
192.168.1.15 company1-15-wideband1
192.168.1.16 company1-16-wideband1
192.168.8.2 company1-16-satcom
192.168.1.17 company1-17-wideband1
192.168.1.18 company1-18-wideband1
192.168.1.19 company1-19-wideband1
192.168.9.1 company1-19-uav
192.168.1.20 company1-20-wideband1
192.168.1.21 company1-21-wideband1
192.168.1.22 company1-22-wideband1
192.168.9.2 company1-22-uav
192.168.1.23 company1-23-wideband1
192.168.1.24 company1-24-wideband1
```

Fig. 18   Host file with experiment scenario hosts

f. Launches the Optimized Link State Routing (OLSR) protocol on the EMANE interfaces on the chosen node (Fig. 19). For example, OLSR is started on interfaces emane0 and emane4 on node company1-1. If one does not want OLSR to run, comment out Line 38 in the "start_emane.sh" script file on all of the nodes.


```
olsrd -f ${CONFIGS_HOME}/routing.conf
```

Fig. 19   OLSR start command in the "start_emane.sh" script file

The routing table output from node company1-1 hosted on cluster node exp-1 is shown in Fig. 20.

```
Connected (unencrypted) to: QEMU (exp-25)
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         10.2.0.2        0.0.0.0         UG    0      0        0 eth0
10.0.1.0        0.0.0.0         255.255.255.0   U     0      0        0 lxcbr0
10.2.0.0        0.0.0.0         255.254.0.0     U     0      0        0 eth0
172.15.0.0      0.0.0.0         255.255.255.0   U     0      0        0 eth1
172.16.0.0      0.0.0.0         255.255.255.0   U     0      0        0 eth2
192.168.1.0     0.0.0.0         255.255.255.0   U     0      0        0 emane0
192.168.1.2     192.168.1.2     255.255.255.255 UGH   2      0        0 emane0
192.168.1.3     192.168.1.3     255.255.255.255 UGH   2      0        0 emane0
192.168.1.4     192.168.1.4     255.255.255.255 UGH   2      0        0 emane0
192.168.1.5     192.168.1.5     255.255.255.255 UGH   2      0        0 emane0
192.168.1.6     192.168.1.6     255.255.255.255 UGH   2      0        0 emane0
192.168.1.7     192.168.1.7     255.255.255.255 UGH   2      0        0 emane0
192.168.1.8     192.168.1.8     255.255.255.255 UGH   2      0        0 emane0
192.168.1.9     192.168.1.9     255.255.255.255 UGH   2      0        0 emane0
192.168.1.10    192.168.1.10    255.255.255.255 UGH   2      0        0 emane0
192.168.1.11    192.168.1.11    255.255.255.255 UGH   2      0        0 emane0
192.168.1.12    192.168.1.12    255.255.255.255 UGH   2      0        0 emane0
192.168.1.13    192.168.1.13    255.255.255.255 UGH   2      0        0 emane0
192.168.1.14    192.168.1.14    255.255.255.255 UGH   2      0        0 emane0
192.168.1.16    192.168.1.16    255.255.255.255 UGH   2      0        0 emane0
192.168.1.17    192.168.1.17    255.255.255.255 UGH   2      0        0 emane0
192.168.1.18    192.168.1.18    255.255.255.255 UGH   2      0        0 emane0
192.168.1.19    192.168.1.19    255.255.255.255 UGH   2      0        0 emane0
192.168.1.21    192.168.1.21    255.255.255.255 UGH   2      0        0 emane0
192.168.1.22    192.168.1.22    255.255.255.255 UGH   2      0        0 emane0
192.168.1.23    192.168.1.23    255.255.255.255 UGH   2      0        0 emane0
192.168.1.24    192.168.1.4     255.255.255.255 UGH   2      0        0 emane0
192.168.5.0     0.0.0.0         255.255.255.0   U     0      0        0 emane4
192.168.5.2     192.168.1.2     255.255.255.255 UGH   2      0        0 emane0
192.168.8.1     192.168.1.13    255.255.255.255 UGH   2      0        0 emane0
192.168.8.2     192.168.1.16    255.255.255.255 UGH   2      0        0 emane0
192.168.9.1     192.168.1.19    255.255.255.255 UGH   2      0        0 emane0
192.168.9.2     192.168.1.22    255.255.255.255 UGH   2      0        0 emane0
224.1.2.8       0.0.0.0         255.255.255.255 UH    0      0        0 eth1
```

Fig. 20 Example routing table for mode company1-1

    g. Finally launches the EMANE event service instances and begins sending location and path loss events to the EMANE event daemons on the nodes.

2) At this point, the emulation is now running and set for a user's experiment. The emulation scenario can be stopped by running the "stop_exp.sh" script file (Fig. 21) from the bootstrap node (node 25).

```
Connected (unencrypted) to: QEMU (exp-25)
root@exp-25:/opt/nato-experiment# ./stop_exp.sh
Stopping EMANE On exp-1...
Stopping EMANE On exp-2...
Stopping EMANE On exp-3...
Stopping EMANE On exp-4...
Stopping EMANE On exp-5...
Stopping EMANE On exp-6...
Stopping EMANE On exp-7...
Stopping EMANE On exp-8...
Stopping EMANE On exp-9...
Stopping EMANE On exp-10...
Stopping EMANE On exp-11...
Stopping EMANE On exp-12...
```

Fig. 21 Execute the "stop_exp.sh" script file to stop the experiment

4.   Conclusion

The NATO-IST-124 experimentation environment provides a common platform to explore research issues relevant to heterogeneous tactical networks, including routing topology architectures and their impact on delivery rates, overheads, and scalability; data dissemination protocols; quality of service and resource management; and leveraging and integration of sensor networks. This report details an example use case of launching the EMANE emulation of the first company from the NATO-IST-124 experimentation scenario within ARL's DAVC environment. The instructions provided can be used as a guide to launch various subsets of the entire 273-node emulation scenario for a wide range of experimentation backdrops.

List of Symbols, Abbreviations, and Acronyms

ARL   US Army Research Laboratory

DAVC   Dynamically Allocated Virtual Clustering

EMANE   Extendable Mobile Ad-Hoc Network Emulator

NATO   North Atlantic Treaty Organization

NSRL   Network Science Research Laboratory

OLSR   Optimized Link State Routing

VNC   virtual network computing

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